

π^0 photoproduction off the proton at forward angles using CBELSA/TAPS

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for the CBELSA/TAPS Collaboration

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1 Introduction

Motivation

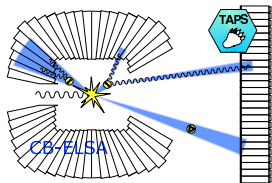
The CBELSA/TAPS Experiment at ELSA/Bonn

2 Observables

Differential Cross Sections

Photon Beam Asymmetries

3 Summary and Outlook



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Baryon resonances have large widths and overlap

→ Difficult to extract resonance parameters from the data

- Differential cross sections and polarization observables
 - Measurements needed off protons and neutrons to all possible final states
 - Full angular coverage is desirable

Why study pion photoproduction observables?

- Constrain parameters of known resonances
 - Database is πN scattering dominated
- Search for missing resonances
 - Polarization observables provide access to resonances that couple weakly to πN
- Understand t-channel/u-channel contributions
 - Few measurements are available at very forward/backward angles and/or higher photon energies

Beam-Target Polarization Observables

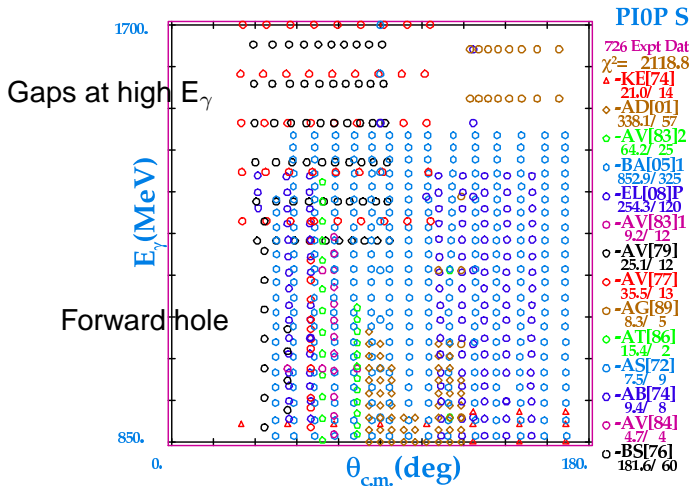
$$\frac{d\sigma}{d\Omega} = \sigma_0 \left\{ 1 - \delta_I \Sigma \cos 2\phi \right. \\ \left. + \Lambda_x (-\delta_I \mathbf{H} \sin 2\phi + \delta_{\odot} \mathbf{F}) \right. \\ \left. - \Lambda_y (-\mathbf{T} + \delta_I \mathbf{P} \cos 2\phi) \right. \\ \left. - \Lambda_z (-\delta_I \mathbf{G} \sin 2\phi + \delta_{\odot} \mathbf{E}) \right\} \quad \Leftarrow \text{Single-Meson} \\ \text{Final States} \\ \text{(7 Observables)}$$

Photon Pol.		Target Pol. Axis		
		x	y	z
unpolarized	σ		T	
linear	$-\Sigma$	H	-P	-G
circular		F		-E

T, P, and H: J. Hartmann, Parallel Session II-A

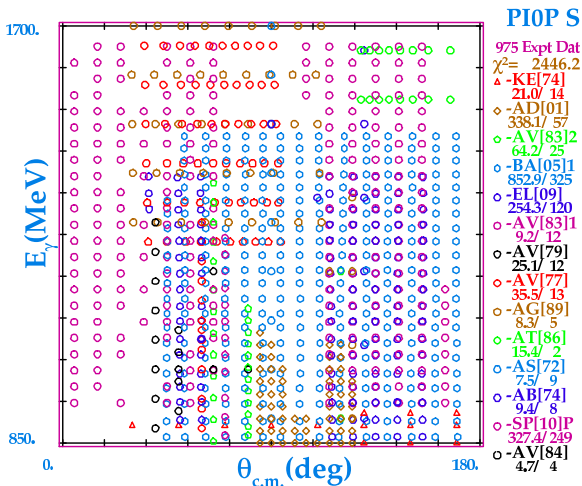
Beam Asymmetries Database for $\vec{\gamma} p \rightarrow p\pi^0$

Before New Analysis



SAID website: <http://gwdac.phys.gwu.edu>

Beam Asymmetries Database for $\vec{\gamma} p \rightarrow p\pi^0$ After New Analysis



SAID website: <http://gwdac.phys.gwu.edu>

CBELSA/TAPS Collaboration, Phys. Rev. C **81**, 065210 (2010)

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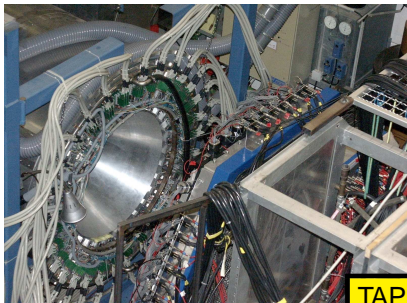
2 Observables

Differential Cross Sections

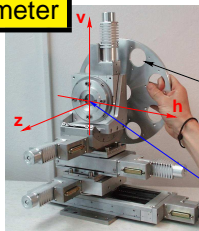
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The CBELSA/TAPS Experiment



Goniometer



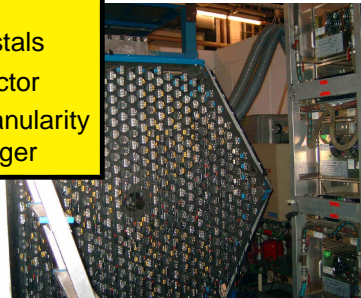
- amorphous radiators
- screen
- empty position
- wires for determination of beam profiles
- diamond crystal

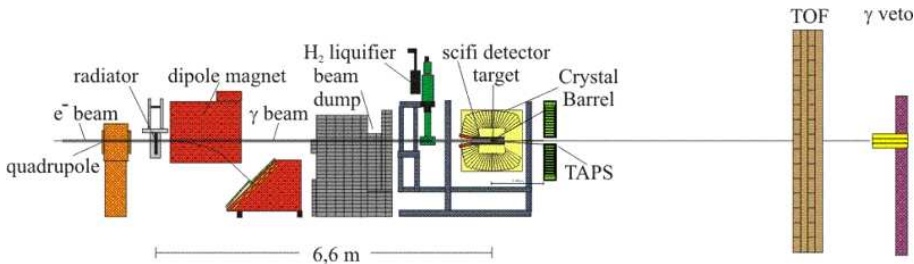
TAPS

- 512 BaF Crystals
- Forward detector
 - High Granularity
 - Fast Trigger

Sep. 2002 – Dec. 2003

- (un)polarized beam
- liquid H₂, deuterium
- solid targets

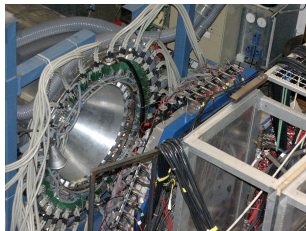




Tagged Photons ($E_{e^-} = 3.2$ GeV):

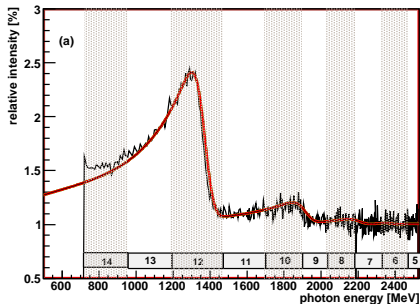
- $0.25 \cdot E_{e^-} \leq E_{\gamma} \leq 0.95 \cdot E_{e^-}$

$\rightarrow 800 \text{ MeV} \leq E_{\gamma} \leq 3000 \text{ MeV}$

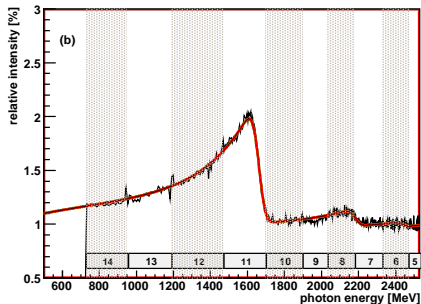


Linearly Polarized Photon Datasets

1305 MeV Coherent Peak



1610 MeV Coherent Peak

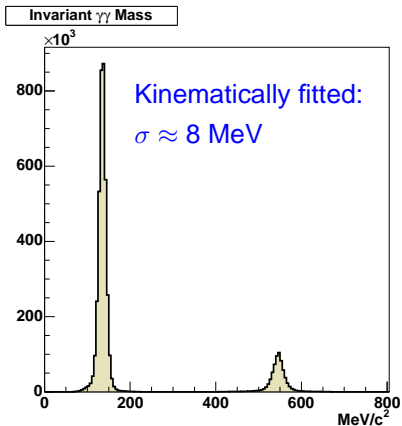


Maximum Degree of Polarization:

- 50% for 1305 MeV coherent peak (March 2003 data)
- 40% for 1610 MeV coherent peak (May 2003 data)

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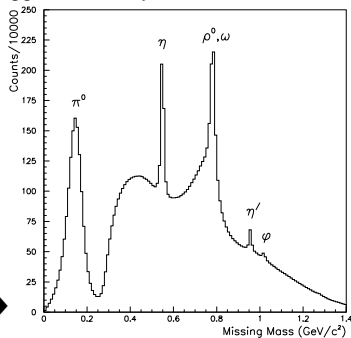
December 2002 Data: Study of $\gamma p \rightarrow p\pi^0$



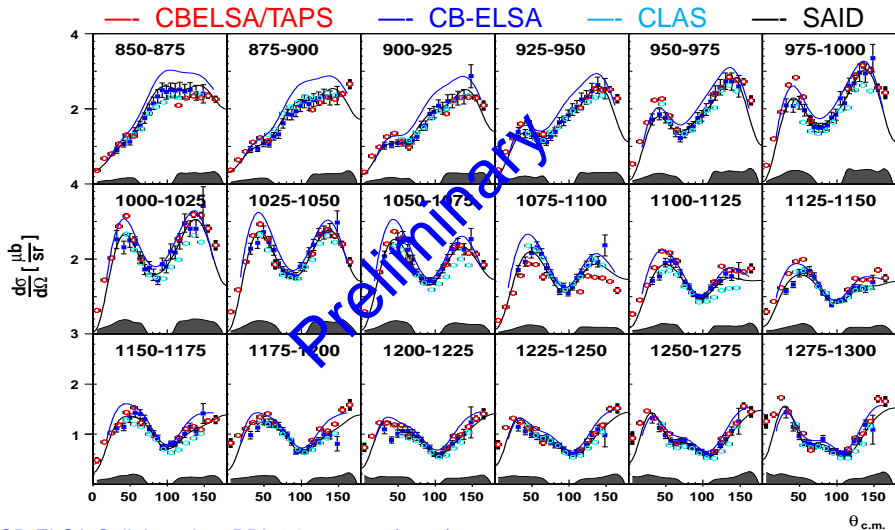
$\gamma p \rightarrow p X$ (missing mass)
(CLAS)

← $\left\{ \begin{array}{l} \gamma p \rightarrow p \gamma \gamma \\ \text{(CBELSA/TAPS)} \end{array} \right.$

M. Dugger et al., Phys. Rev. C **76**, 025211 (2007)

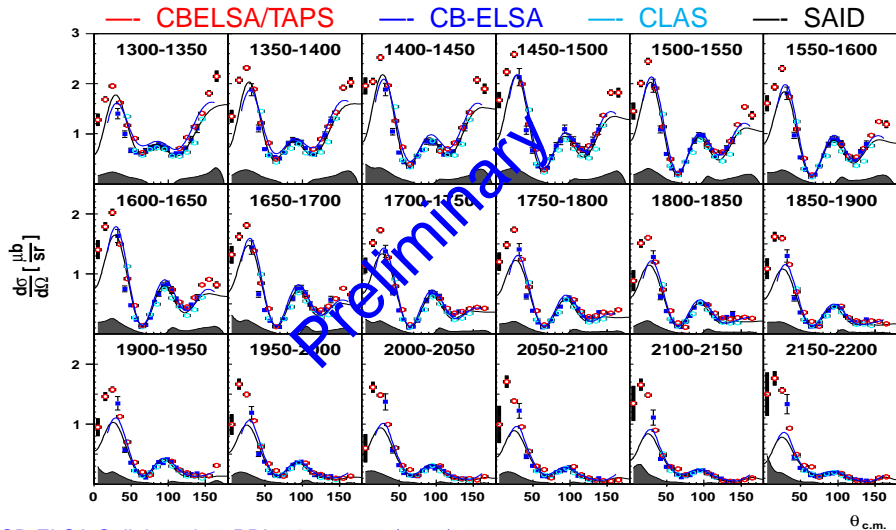


Differential Cross Sections for $\gamma p \rightarrow p\pi^0$



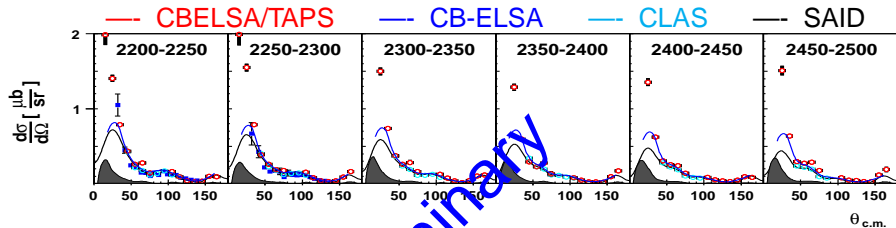
CB-ELSA Collaboration, PRL **94**, 012003 (2005)

Differential Cross Sections for $\gamma p \rightarrow p\pi^0$



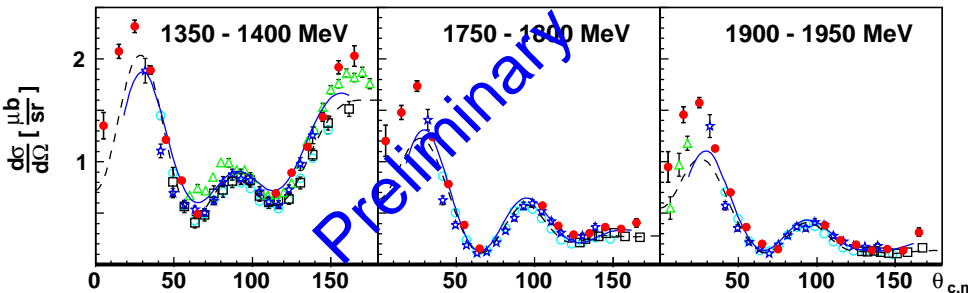
CB-ELSA Collaboration, PRL **94**, 012003 (2005)

Differential Cross Sections for $\gamma p \rightarrow p\pi^0$



Closeup Comparison and PWA Highlights

— CBELSA/TAPS — CB-ELSA — CLAS - - - SAID



CB-ELSA Collaboration, PRL **94**, 012003 (2005)

PWA Highlights

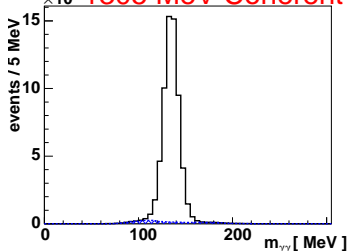
Bonn-Gatchina PWA found contributions from 3 higher-mass N^* states:

- $G_{17}(2190)$, $D_{13}(2170)$, and $D_{15}(2070)$

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March and May 2003 Data: Study of $\vec{\gamma} p \rightarrow p\pi^0$

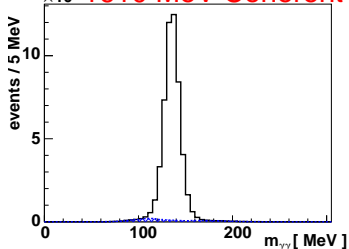
$\times 10^4$ 1305 MeV Coherent Peak



Reconstruction

- Require $\pi^0 \rightarrow \gamma\gamma$ and a proton in final state
 - Missing proton kinematic fit
 - Require confidence level larger than 1%
- Timing cut of -5 to 15 ns

$\times 10^4$ 1610 MeV Coherent Peak



Statistics in Peaks

- 0.69 M events in March 1305 MeV
- 0.59 M events in May 1610 MeV

Background Subtraction

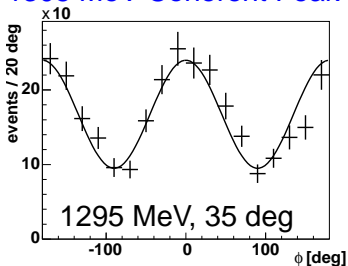
- Use method that assigns signal 'probability' to each event
- $\approx 4\%$ background

Study of Beam Asymmetries in $\vec{\gamma} p \rightarrow p\pi^0$

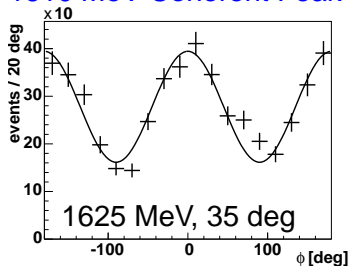
Phi bin method

- Polarized cross section for single pseudoscalar meson photoproduction for linearly polarized beam on unpolarized target
- $\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_0 (1 + P_\gamma \Sigma \cos(2\phi))$
- Fit ϕ distribution for each $E_\gamma, \theta^{\text{c.m.}}$ bin with $N(\phi) = A + B \cos(2\phi)$ $\rightarrow P_\gamma \Sigma = B/A$

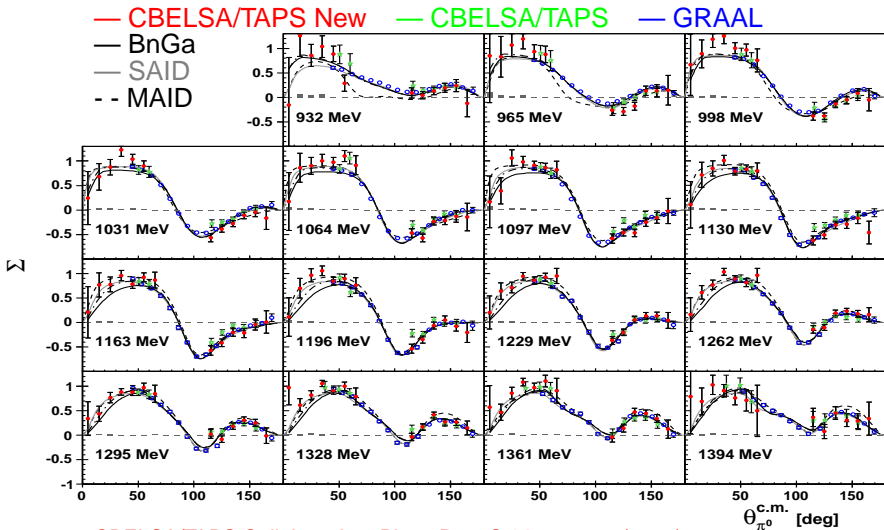
1305 MeV Coherent Peak



1610 MeV Coherent Peak

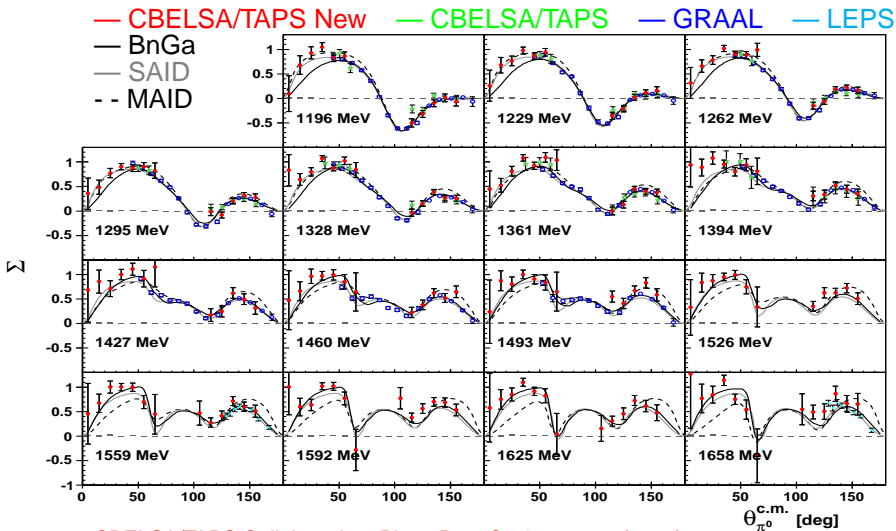


Σ for $\vec{\gamma} p \rightarrow p\pi^0$: 1305 MeV Coherent Peak



CBELSA/TAPS Collaboration, Phys. Rev. C **81**, 065210 (2010)

Σ for $\vec{\gamma} p \rightarrow p\pi^0$: 1610 MeV Coherent Peak



CBELSA/TAPS Collaboration, Phys. Rev. C **81**, 065210 (2010)

π^0 Photoproduction off the Proton

World database greatly enhanced during past several years

- These CBELSA/TAPS data provide nice angular coverage in forward region, which is complementary to previous CBELSA/TAPS data
 - Overall good agreement with previous π^0 data in overlapping regions (CB-ELSA, CLAS, GRAAL, LEPS)
- Observables measured over full angular range help in the extraction of resonance parameters in PWA
- Beam asymmetries published in *Phys. Rev. C* **81**, 065210 (2010)
- Cross sections are currently under collaboration review (to be submitted to *Physical Review*)